"Masters" of Time: Chrono-Biologizing Sleep in the 20th Century

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Hannah Ahlheim & Jonathan Holst *

Abstract: *»‚Herren‘ der Zeit. Die Chronobiologisierung des Schlafs im 20. Jahrhundert«.* In 20th century Western societies, the question if human beings could “master” their sleep and sleeping time became increasingly relevant. Scientists from several fields set out to find the principles of basic body rhythms, debating about the effects of “cosmic forces,” the influence of light and temperature, and the power of will and habits. To conduct their experiments, these researchers turned places like hospital rooms, caves, or bunkers into chronobiology laboratories. It is argued that the now dominant concept of a “clock” inside the body regulating the alternating phases of sleeping and waking was only one of various possible answers to the question of the how, why, and when of sleep. In the course of the 20th century, experts found very diverse, even contradictory explanations for diurnal rhythms, depending on the context they lived in and technologies they worked with. By conceptualizing experimental spaces not as neutral instances of verification, but as epistemically productive, it is pointed out that the science of sleep did not follow a linear path towards a biological truth called “body clocks” but contributed to the sometimes contingent “making” of scientific concepts that generated reliability only within a specific historical context.

Keywords: Sleep, circadian rhythm, body clocks, experimental system, rhythm history, chronobiology, history of knowledge.

1. Introduction

Around 1900, the German botanist Wilhelm Pfeffer engaged in a new field of research: He began to study the sleep of plants. According to his observations, plants went to sleep every evening by folding their leaves when daylight faded, and they woke up in the morning, stretching and turning their body

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parts in the direction of the rising sun. Pfeffer (1907, 1915) began to wonder what biological mechanism regulated these "sleep movements."[1] Did the plants follow the course of the sun or changes in temperature? Or did they react to signals from inside, in their tissues? To find out, Pfeffer began keeping plant specimens in total darkness. He found that these plants stuck to their habit of folding and stretching their leaves in a relatively stable rhythm of 12 hours even if they had no exposure to daylight.

Today, historians of science and rhythms researchers often remember Pfeffer as one of the discoverers of what has become an unquestioned truth: the existence of "clocks" within living beings telling them when it is time to sleep.[2] This interpretation of Pfeffer's work ignores the fact that he spent his life trying to prove quite the opposite: exogenous control of leaf movements. Only reluctantly did Pfeffer finally admit that there was something like endogenous rhythms, but without developing a concise concept of this phenomenon (Daan 2017, 114). Pfeffer thus represents an uncertain and tentative exploration of the basic rhythms of life at the beginning of the 20th century that did not yet answer the question of what could be responsible for the wavelike up-and-down rhythms of nature.

Even if Pfeffer did not have an answer, though, his tentative search for the origin of rhythmicity and for the principles of sleep can be seen as typical of that time. In the first decades of the 20th century, experts such as botanists and zoologists began to scrutinize sleep as one of the basic rhythms of animal and plant life while, at the same time, physiologists, psychologists, and practicing physicians turned their attention in particular to human beings as rhythmic creatures. Experts began to dream of human emancipation from the natural alternation of day and night, promising a more autonomous and, at the same time, more productive way of life. In this context, the alternation of sleep and wakefulness was the most obvious and most important bodily rhythm: "We can arbitrarily reverse the periodicity of sleeping and waking, we can become night-wakers and day-sleepers," the German neurologist and psychiatrist Ernst Siemerling (1923, 14) stated in 1923, "without any disturbance of the organism." Siemerling raised a question that bothered not only researchers and scientists but also physicians, psychiatrists, mothers and fathers, and employers and employees throughout the 20th century: To what degree could the human being act as "master of that period" ("Herren dieser Periode") and change its rhythms of sleep "deliberately" (ibid., 17)?

We want to take Pfeffer's and Siemerling's questions as a starting point for our history of the "Chrono-Biologization" of sleep in 20th-century Western industrialized societies. By following the experts in their search for the "pacemaker" responsible for the rhythmicity within the organism and, especially,

[1] All German and French references are translated by the authors.

[2] This interpretation owes much to the biologist Erwin Bünning (Bünning and Chandrashekaran 1975; Bünning 1977, 2-3).

within the human subject, we aim to understand the close intertwining of the conflicting needs of a modernizing society and the rise of specific scientific concepts. Today, societal debates over rhythmic health, involving objectives such as following biocompatible schedules at school and work, rely on the ubiquitous concept of the "body clocks" (Williams, Meadows, and Coveney 2021). It is not our goal, however, to (re)write a straightforward history of that successful scientific concept as a stepwise developmental approach to a biological truth. Such a teleology does not do justice to the plurality of history, with its epistemic ruptures and contradictory concepts that can be understood only in terms of their own, historically situated aspirations.[3] We want to point out that the making of the "biological clock" was a complicated story of tentative searching in multiple directions, of trial and error, and sometimes even of contingent circumstances in a very specific laboratory space. Over the course of the 20th century, experts found very diverse answers to questions about the how, why, and when of sleep. Each answer, of which the "internal clock" was only one, represented a product of multiple questions, shifting experimental settings and a range of interests that created an understanding of the human that was bound to a specific historical situation.

The history of this scientific endeavor, now known as "chronobiology,"[4] has drawn increased academic attention in recent years. Professional historians have just begun to take an interest in this strand of science (Ahlheim 2018; Shackelford 2022; Hussey 2022a).[5] Before, for a long time, it was mainly chronobiologists themselves who had undertaken the task of writing their own history (Daan 2009, 2017; Foster and Kreitzman 2005; Ward 1971). Given the inner logic of disciplinary traditions, in which history is primarily a resource for legitimizing contemporary scholarship and reinforcing a collective identity, conventional narratives of chronobiology often feature three blind spots that we aim to overcome by choosing a genuine historical approach.[6] *First*, there is an immanent teleology when chronobiologists place a long-rejected but timeless truth at the heart of their own discipline's history: They have taken for granted the eternal existence of an "inner rhythm" of plants, animals, and humans that science had only just discovered. Like the intellectual historian Arthur Lovejoy's (1936) concept of a "unit-idea," the

[3] Probably most prominently, George Canguilhem (1968) and Michel Foucault (1969) have opposed such thinking, which understands the present as the culmination of a passage from an origin.

[4] For a long time, this term was controversial among rhythm researchers. For a history of these debates, see Cambrosio and Keating (1983).

[5] Recently published is Jole Shackelford's (2022) three-volume *Introduction to the History of Chronobiology*. At the time of the editorial deadline, only Volume 1, *Biological Rhythms Emerge as a Subject of Scientific Research*, could be consulted.

[6] Abi-Rached and Rose (2010) have diagnosed very similar blind spots with respect to the history of the "neurosciences." While we largely agree with the authors at the level of diagnosis, our own approach differs from that of Abi-Rached and Rose because it is much more practice-oriented.

concept of the “internal clock” seemingly moved through space and time toward a predestined, widespread recognition. According to this narrative, each scientist thus turns into a possible precursor of the “triumvirate Aschoff-Bünning-Pittendrigh,” (Chandrashekaran 1998, 555) researchers who are revered today for having founded the field of chronobiology in the 1960s. The decisive question seems to be who made the discovery – and when. Did Nathaniel Kleitman, the “father of sleep research” (Foster and Kreitzman 2005, 177), already anticipate the concept of the “inner clock” in the 1930s? Or did the 18th-century French astronomer de Mairan or even the Greek philosopher Androsthenes know about the “internal clock”?[7] The quest for precursors fabricates a linear history of progress which stands in favor of a contemporary truth. In a Platonic anamnetic gesture, chronobiologists could proclaim that their truth was always there and was only to be discovered or remembered.[8] In addition to the anachronism involved in ascribing to historical actors a concept of the “internal clock” for which they plainly did not advocate,[9] the quest for a precursor is problematic for a more general reason. We do not want to deny that the metaphor of the “internal clock” had already circulated occasionally before the institutionalization of chronobiology in the 1960s, but a linear prehistory of this concept obscures the historical plurality of chronobiological interpretations. Against which alternative notions did the “internal clock” prevail and why?

To answer this question, it is necessary to overcome a *second* blind spot, which has long been disavowed under the term “internalism” (Canguilhem 1968)[10] but lives on unswervingly in the narratives of chronobiology. According to this view, science is a self-contained domain in which individual scientists, concepts, and paradigms compete for dominance relatively uninfluenced by overall societal dynamics. Instead, when we analyze science as a social practice, we understand knowledge of the sleep-wake rhythm as ineluctably culturally shaped as well as socially powerful.

To us, chronobiology laboratories are not islands of truth but have always been part of society. From the beginning, the scrutinizing of sleep and of bodily rhythm has been bound to everyday experiences and the needs and conflicts characteristic of an industrialized society. Sleep study sprang from practical experiences as well as from the philosophical, scientific, and artistic need to come to terms with “modernity.” Since the late 19th century, contemporaries have experienced the acceleration and rhythmization of the world,

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7 Such characterizations occur, for example, in Foster and Kreitzman (2005, 16, 178); Chandrashekaran (1998, 546).

8 On the anamnesis strategy in the history of science, see Feyerabend (1975).

9 Serge Daan (2016), for example, revised his earlier interpretation of de Mairan (1678–1771) as the first discoverer of an endogenous rhythm after reading the botanist’s original writings and then used this anecdote to illustrate a central pitfall of the historiography of his own scientific speciality.

10 On overcoming the dichotomization of internalism and externalism, see Shapin (1992).

pushed by the introduction of mechanized production methods, mass media, cultural habits, and faster transportation networks, and accompanied by the widespread use of mechanical clocks and timetables. Moreover, electricity made new forms of nightlife and night-work possible, and the boundary between day and night dissolved. Time was everywhere, and the contrast between rhythms understood as "natural" and those of technical devices was an everyday experience (Cowan 2011, 42). Rather than telling the history of chronobiology as an internalist history of science (Shackelford 2020; Bechtel 2016; Foster and Kreitzman 2005; Cambrosio and Keating 1983), this paper is thus concerned with the interweaving of science with social norms, political interests, and changing everyday routines. In tackling the problem of biological time, scientists have not only profoundly shaped our ideas about sleep, but they have also changed how Western societies think about individuals as temporal beings and how they imagine human bodies in their environments. Finally, yet importantly, the search for the "biological clock" seeks an answer to one of the great questions of "modernity": to what extent can societies and individuals exercise command over time?

One of the most productive approaches to analyzing science as social practice over the past 40 years has been that of "Laboratory Studies" (Knorr Cetina 1981, 1995; Latour and Woolgar 1979). The *third* blind spot we want to overcome, consequently, is neglect of experimentation. No doubt, historians of science and chronobiologists have discussed numerous experiments that scientists since the late 18th century have conducted.[11] Yet in so doing they have remained quite logocentric: the experiment does not have a life of its own, is not a site of contingency and negotiation, but, in the tradition of Karl Popper (1959), simply serves to validate thought. Science thus takes place solely on the level of conflicting concepts, not on the level of practices, whether local or material.

Chronobiology laboratories thus appear as factories of knowledge, where truth itself finally comes into its own against all historical hindrances (Chandrahekaran 1998, 545; Webb 1994, 189-90). Along these lines, conventional narratives are populated by a handful of heroes, revered today as "flamboyant" personalities (Daan 2009, 9), "popes" (Daan 2017, 229), or "big boys in the game" (Chandrashekaran 1998, 545). With their "rich-timbred, bold voice[s]" (ibid., 547) the story goes, they helped the truth of the "internal clock" finally gain acceptance (Daan 2000; DeCoursey 2004). The social element of science is here reduced to an ex-post persuasion involving "discovered" facts.

In the spirit of laboratory studies, then, we instead assume that knowledge necessarily involves a social component that inscribes itself directly into the fundamental concepts themselves. It is our aim to open the black box of sleep knowledge by analyzing how this knowledge was produced in various

[11] For a detailed discussion of a range of experimental designs, see Webb (1994); Lavie (2001); Zulley and Knab (2015); Czeisler (2007).

experimental settings through a social process.[12] Moreover, from a spatial-historical perspective, chronobiology laboratories appear by no means self-evident. To take up a central distinction posited by Michel de Certeau (1990, 172-5): The spaces of chronobiology, where scientists, experimental animals or subjects, and technical apparatuses interacted, were not simply there. Rather, over the course of the 20th century, scientists selected various places (*lieux*) and turned them into experimental spaces (*espaces*) in the first place. We examine this process of laboratorization with a focus on – in addition to everyday life – two laboratory-like spaces: the cave and the bunker. These sites and their "experimental systems" (Rheinberger 1997, 2021), we argue, were fundamental to what we call the "chronobiologization" of sleep. Rather than constituting neutral instances of verification, they were epistemically productive. Through specific temporalizations of experimental spaces, they each prefigured specific ways of controlling time while excluding others. As closed as they were supposed to be to the outside world, they were always permeable by social norms. Finally, they were spaces where new and unexpected things could happen.

In what follows, we examine three historical phases, each of which was dominated by a specific experimental design linked to a specific interpretation of the extent to which people can become "masters" of their own sleep. We begin by looking at the period spanning the late 19th and early 20th centuries, when several experts began to develop distinct, even conflicting, concepts of the "nature" of bodily time and tried to validate their ideas with the help of specific experimental settings. In this first phase, rhythm researchers moved their experimental systems from everyday environments to sealed-off cave laboratories. There was also great optimism that people could flexibly change their rhythms through willpower. Until the second half of the 20th century, the fundamental question regarding where and how the rhythm of life and sleep had its origins remained undecided (see "Spaces in Time" below). Only the rise of a specific experimental space, the timeless "bunker," finally seemed to lead to a widely acknowledged, unchallenged, universal concept of "internal rhythms." In this second phase, the experimental system of the bunker replaced the cave as a paradigmatic space of knowledge and produced the authority to demonstrate the very "nature" of bodily time (see "Timeless Spaces" below). In a third phase, the previously separate specialities of chronobiology and sleep research merged through the migration of electroencephalography technology into isolation units constructed

[12] This approach comes closest to what the anthropologist Matthew Wolf-Meyer (2013) did for Kleitman's 1938 experiment in Mammoth Cave, although we disagree with him on a crucial point. Kristin Hussey (2022b) recently looked at the cave as a central site in chronobiology. She is now working on a book project on the history of sleep and time in the Arctic in the 19th century as well as on the book *Body Clock: A History*. Places of knowledge have gained prominence as a concept in recent years through Christian Jacob (2007-11, 2014).

specifically for chronobiological purposes. This resulted in a chronobiologization of sleep that dominates today's debates over good and healthy sleep-wake rhythms (see "Fitting Biological Rhythms into Time" below).

2. Spaces in Time: Conflicting Concepts – or Can Human Beings Willingly "Modify" Their Bodily Rhythms?

In the late 19th and early 20th centuries, several experts from separate fields began scrutinizing the rhythms of life. Their search took place in several spaces, they posed distinct questions, used discipline-specific methods, and came to different conclusions. While botanists such as Wilhelm Pfeffer could observe plants in secluded dark rooms to record their sleep rhythms, scrutinizing the rhythms of human subjects has followed its own logic. In the beginning, the subject of interest in human rhythmicity was the human being in the context of work, productivity, and health. In the second half of the 19th century, physiologists began asking what impact an inversion of the usual daily rhythm of rest and activity work might have on the health and work capacity of the individual. Apparently, night workers were able to reverse their periods of sleep and activity through willpower and concentration during their regular night shifts. But over what exactly did the human being achieve command through this enforced inversion? Could the individual really work at night and sleep during the day without exerting any organic effects? Did the organism itself also adapt to the chosen rhythm, or did night workers have to struggle against their bodily needs?

As an indicator for the actual rhythm of the organism, physiologists chose to measure body temperature. The temperature curve for healthy individuals sleeping at night and working during the day followed a regular and relatively stable pattern every 24 hours. The temperature fluctuated by ½ to 1 degree over the course of the day, with a maximum temperature in the afternoon, when the person was wide awake, and a minimum temperature in the early morning hours, in the middle of the night's sleep (Liebermeister 1875). The experts assumed that the peak of the daily temperature curve coincided with an enhanced capacity to work while a lower body temperature signalized the need for sleep – and posed a problem for those who tried to work during these phases.

Some experiments suggested, however, that the individual could influence this curve by changing daily habits of rest and activity. For example, a study conducted by a Polish physiologist, Debczinki, revealed that the temperature curve of night-working bakers actually did adapt to the inversion of night and day: a baker's temperature curve peaked at 37 degrees at 8 a.m. and then dropped to its minimum in the evening (Toulouse and Piéron 1907, 425). As a result of sustained nighttime work, the "ratio of diurnal variations" seemed to reverse "so that the highest thermometer reading (37.8°) occurs in the morning and the lowest (35.3°) in the evening" (Rosenthal 1880, 323), concluded a physiological compendium in 1880.

At the turn of the century, the well-known French physiologists Henri Piéron and Eduard Toulouse came to the same conclusion. They lived at a time when the paradigmatic site of rhythm knowledge was not yet the laboratory but instead the domain of everyday life. As a perfect subject for their study, they consequently identified nurses and inmates assigned to night watches in a mental asylum in Paris, the *Asile de Villejuif*. Between 1899 and 1905, Toulouse and Piéron (1907, 1906) collected data from a total of 16 subjects over an extended period of 12 to 72 days (Gottesmann 2013). Although the subjects reacted in varying ways to the shift in sleep-and-wake rhythms, the result seemed to be positive: "It is possible to obtain the complete inversion of the nycthemeral rhythm of the temperature in man," stated Toulouse and Piéron (1907, 432). "It is not the cosmic periodicity of day and night that determines the nycthemeral rhythm" (ibid., 430). The 24-hour temperature curve adapted itself to the "modalities of activity" (ibid., 431). With regard to these measurements, the French physiologists assumed that human beings could assume command over their own bodily periodicity by simply changing their rest and activity habits (Toulouse and Piéron 1906, 617). From this perspective, sleep appeared as one of those easily manageable habits.

The question regarding if and how an individual was able to adapt the rhythms of the body to the rhythms of work gained momentum in the course of the 20th century. The number of people forced to work at night and sleep during the day increased from decade to decade, and the pace of life still seemed to accelerate. The idea of human flexibility had a powerful counterpart, however, as indicated in the foregoing quote. With regard to humans' diurnal rhythm, the idea that a "cosmic" environmental factor controlled it from the outside persisted. In numerous popular sleep-related advice books in the first decades of the 20th century, the concept of a universal "cosmic rhythm" figured as an anti-modern and mystical counter-interpretation against the supposedly rational and accelerated modernity (Ahlheim 2018, 256). Yet the interpretation remained prevalent even in the course of expanding empirical research into biological rhythms: The exogenicists considered empirical evidence to be on their side. They argued that only the "cosmic" factor could explain the shifting of the temperature curve according to local time during long ship journeys. Moreover, many other experiments could not reproduce Piéron and Toulouse's findings, and some rhythm researchers interpreted the higher temperatures they had measured during night work as a mere short-term effect of increased movement, not evidence of an alteration of the ongoing normal rhythm (Völker 1927, 69-71).

In addition to the two already conflicting ideas of the human being as "master" of his/her body rhythms and of a powerful external "cosmic" factor also reigning over the human body, around 1920 the Viennese physiologist Josef Szymanski (1922, 221) developed a third concept of corporal rhythmicity: the idea of the “organic clock.” Szymanski was among the first to investigate, with the help of scientific devices, the rhythm of rest and wakefulness in individual specimens and human beings in the specially arranged room of a laboratory. Unlike Piéron and Toulouse, though, he wanted to know how waking and sleeping, rest, activity, and performance sorted themselves within the given framework of 24 hours when they were not pre-structured by external conditions such as working hours or fixed times for food intake. Above all, using an “actograph,” he measured the periodic alternation between rest and activity in various animal species in numerous experiments (Szymanski 1919).[13] This sophisticated apparatus transferred bodily movements of fish, mice, birds, dogs, and babies to a sheet of paper as a series of curves.

Szymanski found that, contrary to the popular notion of sleep, some animal species did not sleep in one uninterrupted block if time, but rather slept in several blocks over the course of the day; they slept “polyphasically” (Szymanski 1914, 344; 1918a, 430-48), as he called it. Inspired by this finding, Szymanski began to look at human sleep as well. First, he studied newborns at the women’s clinic at Vienna University who had not yet been acclimated to a “schedule” and still had to learn to adapt to the rhythms of society. Some of the infants were not nursed according to set times, as was customary at the time, but were put to the breast whenever they had cried for 15 minutes: “In this way, I hoped to be able to determine the spontaneous periods of activity in a 24-hour cycle,” Szymanski (1918b, 429) explained. While the periods of rest for infants that were regulated according to a clock setting began to follow a predetermined schedule, infants who were breastfed according to their needs slept a completely different sleep from that of adult humans. Much like mice and rabbits, infants who followed their own rhythms did not experience an uninterrupted “night’s sleep” once a day, but rather obtained rest in several phases throughout the day. These young children proved to be “polyphasic organism[s],” Szymanski (1918b, 429) concluded. Adult subjects, however, whom Szymanski had painstakingly measured in the laboratory of Basel University’s psychiatric clinic lying in bed for more than 24 hours while remaining “as completely physically and mentally passive as possible” showed a monophasic sleep pattern – “as one might expect,” commented Szymanski (1922, 201, 209).

With his study, Szymanski believed he had proven that all organisms followed rhythmic patterns that repeated every day independently of any external natural changes in night and day, temperature, or light. He assumed, therefore, that the rhythm of rest and activity followed the pace of an “organic clock,” as he called it in 1922: An “organic clock on which the consciousness

[13] For the use of the actograph in the history of chronobiology, see Schwartz and Daan (2017, 15-7).

reads the time" (ibid., 221).[14] This clock, according to Szymanski, followed a rhythm that was typical for each species.

While only devoted experts in rhythm research know the names and studies of Wilhelm Pfeffer and Joseph Szymanski today, another experiment designed to reveal the principles of bodily rhythms in human beings is widely known: the famous "Mammoth Cave experiment" of 1938. On June 4, Nathaniel Kleitman, professor of physiology at the University of Chicago, moved into a cave, together with his doctoral student, Bruce Richardson. The "Mammoth Cave experiment" made Kleitman famous throughout America and even Europe, at least for a few days. The pictures of the two men, who lived, worked, and slept underground in hoodies with camping gear and complex scientific apparatuses, went viral. Newspapers reported on the experiment, *Life Magazine* produced photo coverage, a film crew bored its way to the cave, and Kleitman had to give countless interviews. Apparently, the scientists' concern with establishing a new rhythm attracted considerable public attention: *Popular Science Monthly* (1938) summarized the goal of the experiment by asking the question, "Can man change his normal living habits and adjust himself to a twenty-eight instead of a twenty-four hour day?"

Taking up the questions that Piéron and Toulouse had pursued, the two Chicago scientists tried to learn whether it was possible "to modify the body-temperature cycle by changing the conditions of existence: sleep, activity, and food intake" (Kleitman 1939, 253). Kleitman's previous attempts to establish alternative rhythms that deviated from 24-hour cycles in everyday life for himself and others had not been satisfactory. In his opinion, this was not least owing to everyday temporal patterns of sunlight and temperature, which made the modification more difficult. The stay deep down in the cave made it possible to get away from these "external conditions favoring the 24-hour cycle,"[15] as Kleitman explained in a letter to Alan Gregg, the director of the *Medical Sciences Division* at the *Rockefeller Foundation*.

To silence the remaining advocates of the cosmic factor, Kleitman and Richardson radicalized Piéron and Toulouse's experiment by transferring it from everyday environments to a cave laboratory. They wanted to establish a 28-hour day and a 6-day week and adapt their basic bodily rhythm (the temperature curve) to that artificial pattern of time. The chosen 28-hour rhythm ensured that the body could not stick to a basic rhythm of 12 hours as simply half of the usual 24 hours. To implement the new time structure, the "day" in the cave started with breakfast, followed by few hours of work under the light of electric lamps. Around the middle of their prolonged day, Kleitman and Richardson took a lunch break, and they finally went to bed after 19 hours for

[14] In 1814, the French pharmacologist Julien-Joseph Virey had already described a "horologe vivante" (Daan 2010, 7).

[15] Letter from Kleitman to Gregg, January 14th, 1938, Rockefeller Archive Center (RAC), Rockefeller Foundation (RF), RG 1.1, 216 A, folder 88.

nine hours of sleep before the next 28-hour-day began. "Naps" during the "day" were not allowed. Both men recorded their movements during sleep with the help of actographs, took long series of blood and urine samples and, most importantly, measured their body temperature regularly.

Through this schedule, oriented to life outside the cave, anthropologists Matthew Wolf-Meyer (2013, 96, 116) argues, the Chicago sleep researchers imposed social and cultural norms on the ostensibly "pure" space of their laboratory. By excluding, for example, the unaccepted nap, they gave their newly created rhythm the culturally standardized form of consolidated sleep at night. Unlike Szymanski, though, Kleitman and Richardson did not want to "clean" their laboratory space from cultural influences. Their experimental underground space was not supposed to be timeless.[16] On the contrary, Kleitman and Richardson needed a space that was relatively "empty" of external time so that they could implement their own special regime of time, enabling them to change the rhythm of sleep and activity as a means of influencing the basic rhythms of the body.

Kleitman argued that recent studies and his own numerous experiments had indicated that the 24-hour rhythm of basic bodily functions, for example the temperature curve, was closely linked to the timing of sleeping and waking. He emphasized that the bodily rhythms seemed to operate at least partly independently of day and night: "Our results," Kleitman explained, "point to the existence of a subcortical 'sleep' mechanism which is responsible for the alternation of sleep and wakefulness without any relation to day and night."[17] This "sleep mechanism" was what Kleitman and Richardson were looking for, and it was supposed to be situated within the human body itself.

The "Mammoth Cave Experiment" was at least partly successful. A press release from the University of Chicago presented the results of the cave experiment as follows: "Adaptation of sleep and activity is possible on a cycle other than the normal twenty-four hour span, Dr. Nathaniel Kleitman [...] said yesterday."[18] While Kleitman's temperature curve did not adapt to the new time pattern, in Bruce Richardson's case the temperature curve clearly showed "that the temperature cycle is dependent upon the routine of the individual, that is, his sleep, his activity, his food, his play."[19] In some people, the basic rhythms of the body seemed to be changeable without much effort. Kleitman took that as a demonstration of his hypothesis: There is "no foundation for assuming that some cosmic forces determine the diurnal cycle of function, aside from 'rest, movement, food intake and sleep'" (Kleitman 1939, 263-4), he stated. The parameters responsible for a 24-hour cycle could rather

16 This is what the medical historian Kristin Hussey (2022b) erroneously claims.

17 Letter Kleitman to Gregg, March 21st, 1934, RAC, RF 1.1, 216 A, folder 88.

18 University of Chicago, Department of Press Relations, August 7th,1938, Special Collections Research Center, University of Chicago Library, Nathaniel Kleitman Papers, box 12, folder 12.

19 Ibid.

be found “in the physiological processes of the organism” than “in some compelling external force” (ibid.).

The two experts were however not at all concerned with finding “natural” sleep in the cave, as Matthew Wolf-Meyer assumes. At the same time, Kleitman and Richardson’s “sleep mechanism” also had little to do with Szymanki’s “organic clock.” In his pivotal work on the “alternating phases of sleep and wakefulness,” Kleitman (1939) discussed Szymanski’s work intensively but without mentioning the concept of an internal clock-like mechanism at all. He did indeed assume that monophasic sleep in humans was related to their corticalization in the course of evolution (Kleitman 1939, 509, 521). However, by implementing an artificial time regime, the Chicago sleep experts intended to prove that the individual’s sleep rhythm, especially the lengths of sleep periods, was thoroughly culturally determined and based on social conditioning. Kleitman did not fancy the idea of a steadily pulsing rhythm rooted in the organism itself. He was interested in the flexibility and social character of the “sleep mechanism” and assumed that changeable habits could govern even the most basic rhythmic functions of the body.

Even though both Kleitman and Szymanski shifted their work from everyday life to a laboratory environment, they temporalized the experimental space quite differently and, precisely for that reason, derived divergent conceptions. Kleitman’s alternative time regime seemed to suggest human flexibility and the ability to achieve command over time. Szymanski’s experiment, on the other hand, avoided a predefined time regime and seemed to indicate the presence of an “endogenous rhythm.” Crucially, neither Szymanski nor Kleitman had been able to prevail with their interpretations. While botanists and zoologists already assumed the ubiquity of “physiological clocks,” with regard to the diurnal rhythm of humans the idea that a “cosmic” environmental factor controlled it from the outside persisted until the 1950s (Jores 1938; Aschoff 1955).

3. The Birth of Timeless Spaces

In this moment of insecurity, marked by competing models for explaining the rhythmicity of human beings, a physician and behavioral scientist entered the stage of rhythm research, a figure who is nowadays remembered as a co-founder of chronobiology. With a radical experiment, he was to break through the concept of the “internal clock” of human beings, which is taken for granted today: This was Jürgen Aschoff and his famous “bunker” laboratory. Previous experiments on humans, Aschoff (1955) announced, had all been misconceived. Whether on ship voyages, in the Arctic, or in caves – human beings had never been consistently isolated from all external influences. That, however, was exactly what Aschoff wanted to do: To place humans in a "timeless" space to observe whether they would produce a rhythm spontaneously. Which space would be suitable for this purpose? For Aschoff, the answer was a space that would be as fully isolated from the outside world as a bunker.

Given his impressive knowledge of the contemporary state of research, it is surprising that Aschoff did not build on Szymanski, who had fallen into oblivion. His impetus drew from two other "sources of thought" (Aschoff 1990). Aschoff was, first, an exponent of a new generation of mainly zoological and botanical rhythm experts for whom assuming internal causation of biological rhythms had become a matter of course. At the landmark "Cold Spring Harbor Symposium on Biological Clocks" in June 1960, now remembered as the founding meeting of chronobiology, Colin Pittendrigh (1960, 160) presented his concept of "circadian rhythms" and thus the creed of an entire generation was established. With a period length of about 24 hours, "circadian rhythms" were "not learned from or impressed by the environment," but "endogenous in the living system." This meant that they were "caused in the organism itself" and that "the periodic environment operates only as a synchronizing agent" (Aschoff 1960, 11). Aschoff (1954) had termed these "periodic factors of the environment" "zeitgeber" (time-givers, time-cues). As the historian Jole Shackelford (2020) has pointed out, the creed of "circadian rhythms" was closely linked to isolation experiments of the kind that Pfeffer, among others, had performed. Plants and many animals such as birds and mammals, which were kept in continuous light or continuous darkness, did not lose the periodicity of their flower and leaf movements or their activity periods but maintained regular daily cycles. The fact that this cycle did not last exactly 24 hours served as proof of an "endogenous rhythm," as a "frequency deviating by a certain [...] amount from that of earth-rotation" (Aschoff 1960, 12) could not be attributed to periodicity in the environment.[20]

While the metaphor of the "internal clock" had been in use since the beginning of the 19th century as a tool for interpreting the results of rhythm experiments with plants, animals, and humans,[21] only Bünning, Pittendrigh, and Aschoff developed a concise concept of the clock. This concept included the heritability of "endogenous rhythms" as well as their biological selection value for organisms that benefited from orientating and organizing themselves in time. In the course of the institutionalization of chronobiology, chronobiologists also discovered history as an argument. That is, they

[20] The first to make this argument in 1832 in favor of an endogenous rhythm in plants was the Swiss botanist Augustin Pyramus de Candolle (1778–1841). See Schwartz and Daan (2017, 5-6). Such a frequency could not have shown up at all in Szymanski's experiments because of the short observation period.

[21] This is true of the botanist August Pyramus de Candolle (1778–1841), the pharmacist Julien-Joseph Virey (1775–1846), and the zoologist Maynard Johnson. For an overview of these researchers, see Schwartz and Daan (2017, 5-6, 9); Reinberg, Lewy and Smolensky (2001); Shackelford (2020, 372).

discovered many of the forerunners known today only after they had already established the concept of the "internal clock."[22] In this way, they invented a tradition and connected disjointed research attempts into a contrived whole that appears like a coherent development only ex post.

Second, Aschoff was strongly influenced by the behavioral research that Konrad Lorenz, Gustav Kramer, and Erich von Holst institutionalized in the late 1950s at the Max Planck Institute of Behavioral Physiology, where Aschoff had also worked since 1958. Instead of thinking of animals as organisms that merely responded to external stimuli, they made a strong case for their ideas of "endogenous stimulus production" (Lorenz 1959, 107) and innate instincts. Konrad Lorenz, in particular, polemicized against competing approaches, which he subsumed under the fighting term "behaviorism" and which he suspected, through their focus on environmental factors, was embraced to promote the communist idea of the "New Man" who could be shaped according to political ideals (Weidman 2021, 9-10, 14-5).

This (imagined) opposition had consequences with regard to the question of how experiments should be designed. Behavioral physiology was opposed to the practice in reflex theory of merely measuring reactions to certain stimuli. "This experimental arrangement does not grant the central nervous system any opportunity at all to show that it can do other things than respond to stimuli," Konrad Lorenz (1959, 106) stated in his opening address at the Max Planck Institute for Behavioral Physiology: "It can only confirm, not refute, the preconceived notion that this is the only essential performance of the central nervous system, indeed, of the whole animal. 'Animal non agit, agitur', as Descartes already put it, the animal does not act, it is moved." Against this traditional experiment Lorenz and von Holst apposed another experimental design, which was to leave "the investigated system under constant and controllable conditions on its own" (ibid., 107).

Against this background, Aschoff (1960, 12) was not only convinced that the only irrefutable proof of an "endogenous rhythm" would be the experimental observation of a "spontaneous frequency or, to use Pittendrigh's phrase, the free running period," as he himself had already demonstrated in animals. He also stated that no such experiment had been carried out with human beings. So far, experiments in the tradition of Piéron had investigated reactions only in the diurnal rhythms of various bodily functions when subjects artificially modified their activity periods or were exposed to local time shifts while traveling. Whenever the rhythm was supposedly left to itself, however, the exclusion of external factors had not been complete, according to Aschoff (1955,

[22] "Remember: it was not until 1960 that De Mairan's initiating role was pointed out to us by Bünning, and only in 1974 that we learned of Virey who first used the term 'l'horologe vivante'"; Aschoff (1990, 182). A more detailed historization of this process of tradition-making from the 1960s onward and its legitimizing role in the institutionalization of chronobiology has yet to be undertaken. On the self-historization of ethology, see Gräfe and Stuhrmann (2022).

570), because the subjects were still aware of the actual time of day; in other words, “sociological-psychological zeitgebers” were still active. This would explain why so far, in experiments, no free running period was apparent, but the temperature rhythm continued within the usual 24 hours.

With recourse to the recently established concepts of the “circadian rhythm” and the “zeitgebers” as well as the influence of a behavioral-physiological farewell to orthodox reflex theory, Aschoff thus constructed an experimental desideratum: human beings had to be completely isolated – “to the exclusion of all zeitgebers” (Aschoff and Wever 1962). When in 1961 he not only received money from the Max Planck Society but also found an empty bunker in Munich, he took the opportunity to carry out a first pilot experiment, which he placed at the heart of a groundbreaking publication one year later:

> The test subjects entered the bunker in the evening and were abandoned to their own devices for at least 8, at the most 19, days after delivering their watches and closing the lock. They were instructed to live “regularly” and to keep a diary of their physical and mental condition. When going to bed, the blanket light had to be turned off; when getting up, it had to be turned on. (ibid., 329)

Hence, unlike Kleitman, Aschoff now had indeed created a timeless space in which the subjects could no longer orient themselves in time and the sleep-wake rhythm became for the first time an epistemic object as a dependent variable. The subjects’ monitoring was comprehensive: in addition to the lighting conditions, a “time marker” recorded the subjects’ movements in bed and the participants themselves measured their temperatures regularly. “Neither from the clinic nor from the street did the slightest noise penetrate into the bunker,” Aschoff emphasized confidently. As exchanging messages between inside and outside was possible only via the so-called “sluice,” “psychological contact with the environment was also reduced to a minimum” (ibid.).

Indeed, what Aschoff had hoped for turned out to be true: The registered activity patterns resulted in a period of about 25 hours – a conclusion that the speleologist Michel Siffre (1963) would also obtain in 1962 when he isolated himself in the abyss of Scarasson for two months to live “hors du temps.” Aschoff’s bunker experiment is considered today the “first and final proof” (Daan 2017, 139) of the “endogenous rhythm” in human beings. In the timeless space, the concept of the “inner clock” had triumphed over the cosmic factor as well as over the habitually malleable rhythm as Kleitman had conceived it.[23]

The contingent experimental space, however, also held unexpected developments that made further research indispensable. Unlike what the isolation

[23] The academically quickly isolated chronobiologist A. Frank Brown, however, was a prominent advocate of the thesis of a cosmic factor until the 1970s (Shackelford 2020).

experiments sponsored by the U.S. government in the context of the Cold War had suggested (Solomon et al. 1961), the first subjects in Aschoff's experiment endured their time out of time surprisingly well. Before the experiment, Aschoff had suspected that humans were unsuited to free-running experiments because of their psychological makeup, but now his assessment turned 180 degrees: humans were not only psychologically more robust than expected but they also proved to be ideal experimental animals because they were able to participate in the experiment by pressing buttons and switches, thus making it possible to measure many distinct physiological functions, the interactions between which promised to provide information about the circadian system (Wever 1979, 1).[24] Two of these rhythms, the sleep-wake cycle and the temperature curve, which Aschoff and his collaborator Rütger Wever had observed, assumed different periods in some of the subjects and lost their otherwise close relationship. So, did humans have not just one clock but several oscillators that interacted with each other?

These and similar questions convinced Aschoff to institutionalize the project and to build a special isolation unit directly on the grounds of his institute in the Bavarian village of Erling-Andechs. From 1964 to 1989, about 400 subjects were to live temporarily in the so-called "bunker." Following the Andechs model, timeless spaces boomed. Whether in Manchester or New York, rhythm researchers established similar isolation units in various places, whose staff often worked together (Daan 2017, 165). Various laboratories thus became part of an internationally networked laboratory landscape. The bunker and then special isolation units had, respectively, succeeded the cave as paradigmatic sites of chronobiology.

Having demonstrated that there is an "internal clock," the researchers were concerned primarily with the mechanism by which the clock worked. To this end, they investigated its interaction with external influences, which they introduced gradually into the laboratory: variations in lighting conditions, social contact, electric fields, and acoustic signals. All this activity confirmed the assumption that human beings had developed oscillators over the course of evolution, which produced a periodicity that deviated slightly from 24 hours and varied slightly from person to person. This free-running period would be synchronized then by external influences in everyday life to conform to the ordinary 24 hours of the conventional calendar. The circadian system was obviously an open system, interacting constantly with its environment. However, could this knowledge be used to improve time regimes in society?

The Andechs "bunker" was the first chronobiological experimental system for researching human rhythms, providing society with ever-new chrono-related knowledge over several decades. The idea proved to be very popular

[24] For a history of the question of what psychological effects a stay in the bunker produced, see Holst (2022).

with sponsors from NASA and the German Ministry of Science, without whom the construction of the isolation unit would not have been possible. In their publications and applications, Aschoff, Wever, and other chronobiologists never tired of emphasizing the practical significance of their basic research. Inasmuch as it promised insights that would be useful for space travel, it was politically relevant in the space race as part of the Cold War. Moreover, when it came to shift and night work or the phenomenon of jet lag, knowledge about the human "internal clock" promised to help in managing virulent social problems (Ahlheim 2018, 472-3).[25] Pointing to individually specific intrinsic periods, for example, the researchers consolidated the older notion of morning and evening types, only the latter of which could work particularly well at night. The idea of various "chronotypes" became the centerpiece of efforts since the 1970s to "humanize" the world of work (Ahlheim 2019). Achieving command over time thus came to depend on biology via the concept of the "internal clock," which on the one hand set limits to the fantasy of flexibility but on the other hand also provided new guidelines for timing society.

4. Fitting Biological Rhythms into Time – or How Natural Is Monophasic Sleep?

The "bunker" as the paradigmatic space of timelessness did not remain static over time. Quite the contrary: the conception of the "timeless space" underwent decisive transformations. It never stood outside of time but was highly time-bound. Perhaps the most important of these transformations occurred in the mid-1970s, when chronobiology and sleep research merged in various international laboratories at the same time, not least in Andechs (Ahlheim 2018, 525-32). Electroencephalography technology, which entered the bunker along with the sleep researchers and was "grafted" (Rheinberger 2021, 94-113) onto the experimental system, permanently changed the "circadian rhythm" as an epistemic object and linked it to sleep. Sleep and rhythm researchers set out to chronobiologize sleep.

From then on, the "bunker" reflected the interests of researchers working in two scientific specialities: chronobiologists had previously traced the biological principles of human rhythmicity primarily on the basis of activity or temperature periodicity while ignoring the sleep of the test subjects as a cerebral process. Sleep researchers on the other hand had been interested

25 The question of the extent to which these possible applications influenced the experimental setting or whether the emphasis on social relevance was merely a rhetorical strategy designed to obtain the necessary funding to conduct basic research without interference remains to be researched.

primarily in the brain since the 1930s (Berger 1934a, 1934b), when by means of electroencephalography they observed the rhythmic sleep structure as a nightly recurring sequence of successive sleep stages (Loomis, Harvey, and Hobart 1935; Aserinsky and Kleitman 1953). The rhythmic pattern of sleep and activity within the 24-hour frame did not play an important role in sleep research. When the sleep experts found, in the early 1970s, that sleep structure changed depending on sleeping times, this sparked their sustained interest in interactions between the two rhythms (Zulley 1979, 16-28). To investigate these interactions, they moved their electroencephalographs (EEGs) into the timeless spaces introduced by chronobiologists.

In 1974, Munich sleep researchers from the Max Planck Institute for Psychiatry began cooperating closely with the Andechs chronobiologists. Trained in sleep medicine, they launched so-called "chronomedicine" at the interface of both specialities and increasingly researched the connection between deviating rhythms and sleep disorders: "Sleep disorders = rhythm disorders?" (Freese 1980, 6) asked the journal *Max-Planck-Spiegel*, a periodical targeting a broad public, in 1980. According to this equation, a person who lived a 40-hour day under timeless conditions simply had a faulty "internal clock" that failed in the 24-hour daily routine of their "natural environment."

Alongside such a pathologization of rhythmically deviant individuals, however, profound changes in experimental design simultaneously resulted in a liberalization of sleep norms. In this context, the investigation specifically of daytime sleep reflects, more than any other issue in the 1980s, the complex interrelationship between the experimental inside and the societal outside. The psychologist and sleep researcher Jürgen Zulley, who had been measuring subjects electroencephalographically in the bunker since 1974, was interested not only in daytime sleep in the context of the outlined coming together of both specialities but also in the agency of the subjects in the contingent space of an experiment, encouraging him to move in this direction in the early 1980s.

Zulley, examining old experimental records, had found that some of the subjects had done what they were told not to do: they slept at their subjective noon time (Zulley and Knab 2017, 129-42). The instructions they had been given had been clear on that. Subjects were supposed to get out of bed at the beginning of their subjective mornings and not go back to bed until they felt their subjective days had ended, thus structuring their days in a conventional way. However, many of the subjects unceremoniously procured their midday rest through trickery or manual dexterity. To avoid leaving any suspicious data traces, they simply lay down on the floor to snooze, or removed the motion sensors from the bed and reattached them only after slumbering, with the intention – according to Zulley's (2017, 134) interpretation – to be officially deemed "good" subjects. This piqued Zulley's interest in napping. Did napping have an unknown meaning that the previous research design had carelessly neglected? Was it perhaps an artificial study design that had itself produced the “endogenous rhythm” it claimed to measure?

Instead of continuing to prohibit napping, in collaboration with New York sleep researcher Scott Campbell, Zulley (1987) made it an object of study itself: as of 1984, napping in the bunker was officially permitted. In a series of experiments, he encouraged subjects to stop organizing their day into morning, noon, and evening and to sleep whenever they wanted, to do nothing, or even to stay on bed rest for several days. This was a new kind of time-free space, which became possible precisely because the EEG enabled permanent monitoring of sleep and wakefulness without subjects’ intervention. In the end about three-quarters of the test subjects also slept between designated periods and, for half of them, the free-running period was again at the earth-appropriate 24 instead of 25 hours (Zulley and Knab 2017, 135).

Campbell and Zulley (1989) concluded that napping was part of the allegedly “normal” biological routine. In addition, being subject to the “circadian rhythm,” human sleep was apparently also influenced by a so-called “ultradian rhythm,” which made it more or less likely that a person would take a nap every 4 hours (Campbell and Zulley 1987, 159). Thus, the polyphasic sleep pattern observed in infants was apparently still present in adults but had simply been eclipsed by the culturally shaped pattern of daily life. Whereas Szymanski and Kleitman had naturalized the norm of consolidated night sleep, Zulley now culturalized it to some extent with reference to the “natural” polyphasic sleep pattern. He sought to find a way to publicize his findings in mainstream media and appeared publicly as an advocate of midday sleep. He worked continually for its “rehabilitation,” as he called it (Zulley and Knab 2017, 129-42).

Until the 1980s, the Andechs chronobiology had thus unreflectively infiltrated the norm of consolidated night sleep, which had prevailed since industrialization (Ekirch 2001), into study design, thus prejudicing a very specific concept of “endogenous rhythm.” Actually, this initially unreflected prejudice in Andechs is exactly what made recognition of the “endogenous rhythm” possible in the first place. If in 1961 Aschoff had not measured a period of activity whose rhythm steadily deviated from 24 hours in the form of a free-running period, the stinging evidence of spontaneous periodicity that seemed to preclude the “cosmic” factor would have failed to appear, and perhaps the bunker would never have become a paradigmatic place of timelessness. Calling the 25-hour period “at least in part an experimental artifact” (Zulley and Knab 2015, 168), Jürgen Zulley emphasizes the historical contingency of the steep history of the human being’s “internal clock.”

Only at first glance, however, can we agree with Wolf-Meyer (2013) that the sleep laboratory as a naturalization device gave the cultural norm of consolidated night sleep the nimbus of the natural way of things. As unreflectively as the Andechs researchers had experimentally presupposed this norm, so impressively did they almost provocatively challenge it in the 1980s. In so doing, they broke with a tradition that had begun with Kleitman. They not only contributed significantly to the fact that polyphasic sleep patterns are increasingly recognized today as a feature of both European and North American societies, where napping has traditionally been rather frowned upon (Steger 2004), they also individualized ideas of healthy sleep rhythms, although they propagated the midday nap primarily for its potential to enhance performance.

The new experimental rationale could become effective only in a specific historical context. First, the changing behavioral expectations of the subjects – Zulley expected them to sleep exclusively according to their individual needs, far away from any norms of everyday life – reflected a process of individualization and liberalization in society as a whole, which had increasingly gained momentum since the 1970s. Second, it is true that the norm of monophasic nighttime sleep persisted for a long time because it seemed incompatible with the work ethic of the postwar boom. Daytime snoozing, though, had already become a subject of heated debate by the early 1980s. A West German public servant, for example, had laid claim to his office siesta in a 1983 "nap trial" and failed miserably in court. By taking a nap during the day, the Mannheim judge reasoned, the civil servant had violated the duty to work hard and reliably (*Der Spiegel* 1989). The beginnings of social negotiations over good sleep were already evident here. Sleep researchers and chronobiologists implicitly took them up in their laboratories and catalyzed them. Scientists thus conceptualized the supposedly timeless space of the "bunker" very differently at different times, producing a range of notions of the normality of the human rhythm depending on the social context.

Beyond these transformations, the bunker experiments finally established the rhythm produced inside the human being as an unquestioned truth in science as well as in the public. Had Bünning (1977, preface) still written about the 1950s that "one got to hear (or even to read) that the assertion of the existence of endogenous daily rhythms belonged to the realm of metaphysics," knowledge of the "internal clock" was now regarded as the result of the best science. For the question of mastering time, that position implied the importance of shaping social time in harmony with biological time. This was not to change with the molecularization of rhythm research in the 1990s (Daan 2009, 18-20; Foster and Kreitzman 2005). As Williams, Meadows, and Coveney (2021) point out, today's concept of the "internal clock" forms the foundation of a "biomedicalization" of sleep and human rhythms in general. This includes not only a pathologization of deviating rhythms that need to be treated, but also the demand placed on the individual to constantly optimize times in sleep, work, or even eating.

5. Conclusion: The Temporality of Timelessness

South West England, sometime between May and June 2018: Equipped with a headlamp, an "adventurer" named Aldo Kane explores a disused nuclear bunker. "That's probably the most ironic thing I've seen since I've been in here," Kane says, holding a defective wall clock up to the camera; it has stopped at 10:18. Yet the adventurer has no idea what time it really is. For he is not underground for a short excursion: he spends ten days without sunlight, social contacts, or indications of time in the former air-raid shelter, hoping to experience first-hand "what life is like completely outside of time."

This sequence is part of the television documentary, "Body Clock: What makes us tick?" that aimed to disseminate chronobiological knowledge and research. The BBC documentary (Cook 2018) not only demonstrates that the idea of the "internal clock" has become a taken-for-granted element of sleep knowledge, but it also reminds us that this truth did not appear from nowhere but was fabricated at a specific site of knowledge with a specific experimental design.

As we have shown, chronobiological experiments and their sites were never simply innocent instances of truth-finding. Rather, they were productive in the sense that they implied and reinforced certain ideas about the extent to which humans could become "masters" of time. From the perspective of recent approaches to the history of knowledge, we have investigated various experimental sites in their particular social settings and with their specific concepts of rhythm, thus disclosing a non-linear, contextualized, and practice-sensitive history.

In the first phase we examined, the idea of changing and managing the "inner rhythm" had a heyday. The euphoria of modifying and mastering time filled the 1920s and 1930s. In the dreams of researchers and experts, people could work, consume, and socialize whenever they wanted with the help of willingly timed sleep. On the horizon there was a vision of a human who would be capable of taking control over his life and his bodily conditions by will and by habit while forging a better life with improved health and rising productivity. A new experimental design was both a product of and a stimulus for this idea. The question of sleep flexibility drew scientists away from observing people in their usual daily lives, shifting them toward isolating subjects in darkened hospital rooms, abandoned mines, and, above all, caves. An experimental isolation paradigm was born that would long outlast radical fantasies of flexibility.

In the second phase, the isolation paradigm found its culmination at a new site: the bunker. Inside the bunker, all external influences could be eliminated. At the same time, it was the locus of a radical change in thinking about rhythm. By the early 1960s, the first goal was no longer to modify the sleep-wake rhythm, but rather to answer the question of its origin: Did the underlying mechanism of biological rhythms lie outside, in the environment, or inside, in the human body itself? Timeless spaces gained currency as a new experimental system and resulted in the idea of a "biological mechanism" that controls time: the mechanism has its own rhythmic pace but is still open to the influences of the social and cultural world. The human being is indeed governed by biology, but at the same time is an open system, always interacting with the environment. This development in rhythm research had normative implications. The temporal organization of society ought to be tied to the demands of biology. Flexibility found its natural limits, which society always risked exceeding. Control over sleep lay not in boundless freedom but in living in harmony with biology.

We demonstrate how chronobiologists met this challenge to adapt social life to biological rhythms by considering a third phase that began in the mid-1970s. The "marriage of sleep research and chronobiology" (Daan 2010) initiated a dramatic change in timeless spaces. Using electroencephalography, researchers for the first time examined sleep, which they now identified with sequences of brain-wave patterns in relation to the daily sleep-wake rhythm. The new possibilities of measurement not only formed the basis for pathologizing certain rhythms but also a new understanding of timelessness suggested a basis for questioning rigid norms of good sleep, such as consolidated night sleep, in favor of plurality. As a result, individuals became responsible for optimizing themselves in circadian ways – a process that the sociologist Simon Williams terms the "biomedicalisation" of human life rhythms (Williams, Meadows, and Coveney 2021).

The history of the human "internal clock" in Western industrialized societies thus appears as a continuous internalization and scientization not only of the clock but also of its disturbances. While Kleitman continued to assume the social made-ness of our 24-hour rhythm, Aschoff and his colleagues naturalized it with the concept of the "inner clock." The history of chronobiology hence seems to be another chapter in the "Hunt for Human Nature" (Milam 2019) that shaped the 20th century. This turn had quite normative implications: A constructivist perspective made it possible to criticize social-time regimes on behalf of individuals with deviant rhythms. The naturalization of the 24-hour day, on the other hand, which took place from the middle of the 20th century onwards, gives that time frame an authority against which any deviation appears potentially pathological. It should not be overlooked, however, that the opposite has occurred with regard to consolidated nighttime sleep. The chronobiologization of sleep has relativized the previously dominant assumption in Western societies that short daytime sleep phases are something "unnatural," and thus also liberalized sleep norms. The concept of the "internal clock" consequently remains ambivalent.

Our investigation also reminds us that the steep historical trajectory of the "internal clock" cannot be related simply as a scientific story of progress or steps on the way to an unchangeable biological truth. Rather, it is a socially situated and thus fundamentally contingent development. Researchers often referred to as the "predecessors" of chronobiology and sleep research did not simply try to reveal or prove the existence of an "internal clock" – finally succeeding in the 1960s. On the contrary: They acted on very diverse assumptions about the principles of rhythmicity and the mechanism of sleep and designed varying experimental settings that enabled them to support their ideas scientifically. Specific time regimes, established in specific spaces such as a hospital, a cave, a laboratory, or a bunker, created unique concepts of rhythmicity and, thereby, unique concepts of human nature.

A closer look at the various experimental systems that scientists have set up over time makes things even more complicated: neither social contexts nor scientists' presuppositions ever determined what happened in chronobiology labs. Rather, there was always an interplay between societal factors and experimental logics, which not infrequently produced surprising results and gave new, unexpected twists to thinking about rhythms. Not least among the new developments, the migration of the EEG technology to chronobiology labs fundamentally changed how scientists thought about sleep as rhythm. As Ian Hacking (1983, 150) put it, "Experimentation has a life of its own." For further research, we therefore plead for an approach that combines the contextualizing view of historians with the practical orientation of laboratory studies to explain scientific change.

The metaphor of the "clock" has indeed been a "driving force in the history of chronobiology research" (Aviram and Manella 2020) but while that is our central argument, it is by no means the only one and for a long time not even the dominant one. Against this background, the "biomedicalization" that Williams, Meadows, and Coveney posit in view of the "internal clock" loses its self-evidence (Williams, Meadows, and Coveney 2021). Even more: From a sociological perspective, history, as we have shown here in its conceptual and experimental disparity, could even become a resource for thinking differently about humans as rhythmic beings, unlike how it is currently conceptualized in the sciences. If one understands knowledge not as an image of an observer-independent reality but as a tool with which individuals and societies can find their way in the world and achieve agency (Haslanger 1999), then the question arises anew: What kind of sleep and rhythm knowledge do we want to produce? History offers a multitude of answers to this question.

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